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(54) **DRY-TYPE TRANSFORMER**

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H01F 27/28 (2006.01)
H01F 27/34 (2006.01)

(52) **U.S. Cl.**
CPC ***H01F 29/025*** (2013.01); ***H01F 27/2847*** (2013.01); *H01F 27/2871* (2013.01); *H01F 27/346* (2013.01); *H01F 2027/348* (2013.01)

(58) **Field of Classification Search**
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USPC 336/55–62, 180–184
See application file for complete search history.

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(57) **ABSTRACT**

A dry-type transformer comprises a winding with a tapping zone, the tapping zone being the zone wherein at least two connections can be made, allowing to change the number of turns of the winding and thus change the turn ratio of the transformer, and with at least a first non-tapping zone, wherein the winding comprises a conductor having, in at least part of the tapping zone, a first width in the axial direction of the winding, and having, in at least part of the first non-tapping zone, a second width in the axial direction of the winding, the first width being smaller than the second width.

14 Claims, 2 Drawing Sheets

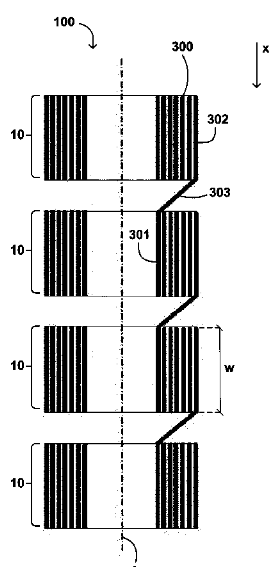

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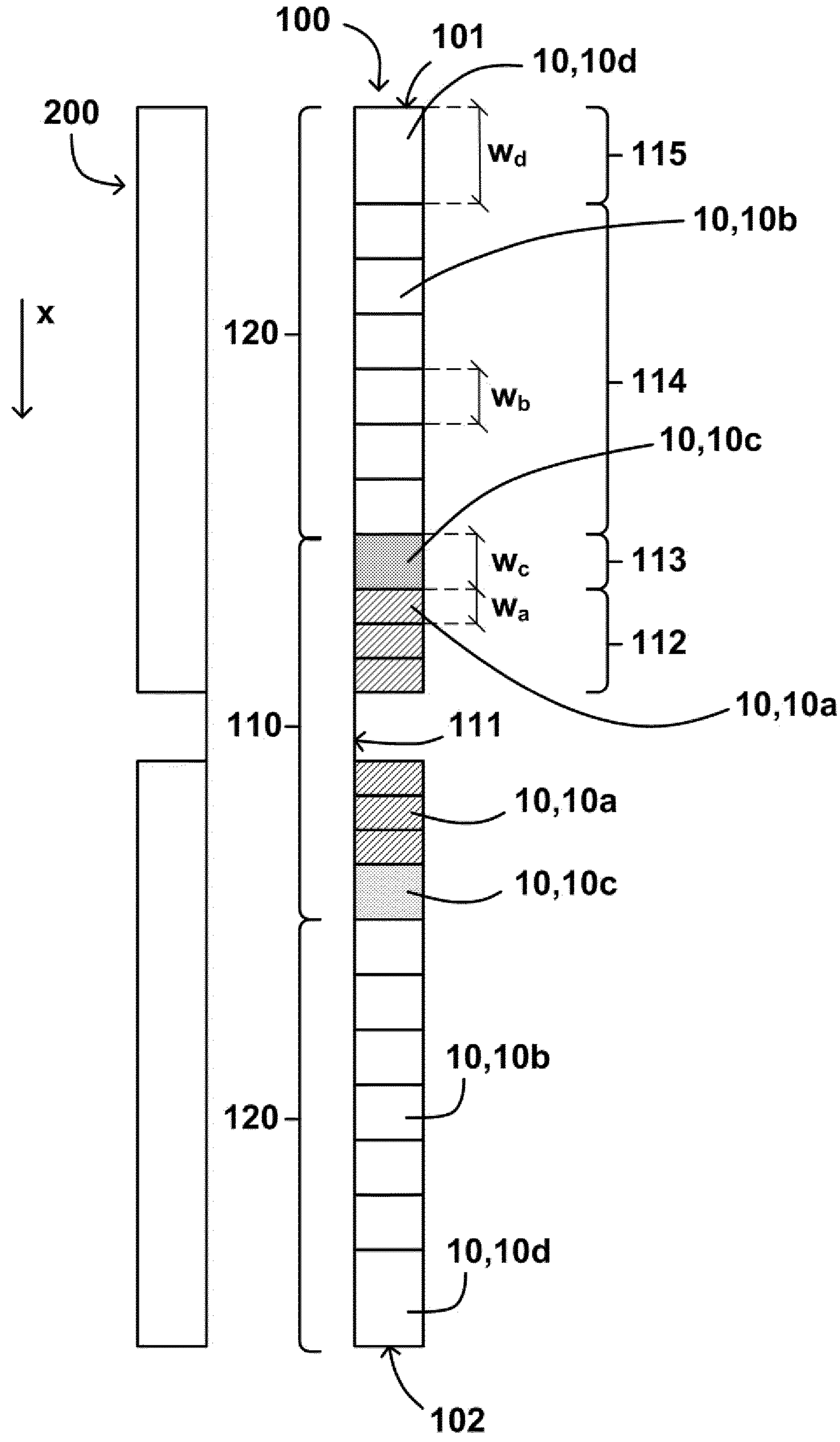
FIG.1


100
101
10,10d
200
w_d
115
10,10b
x
120
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w_b
10,10c
w_c
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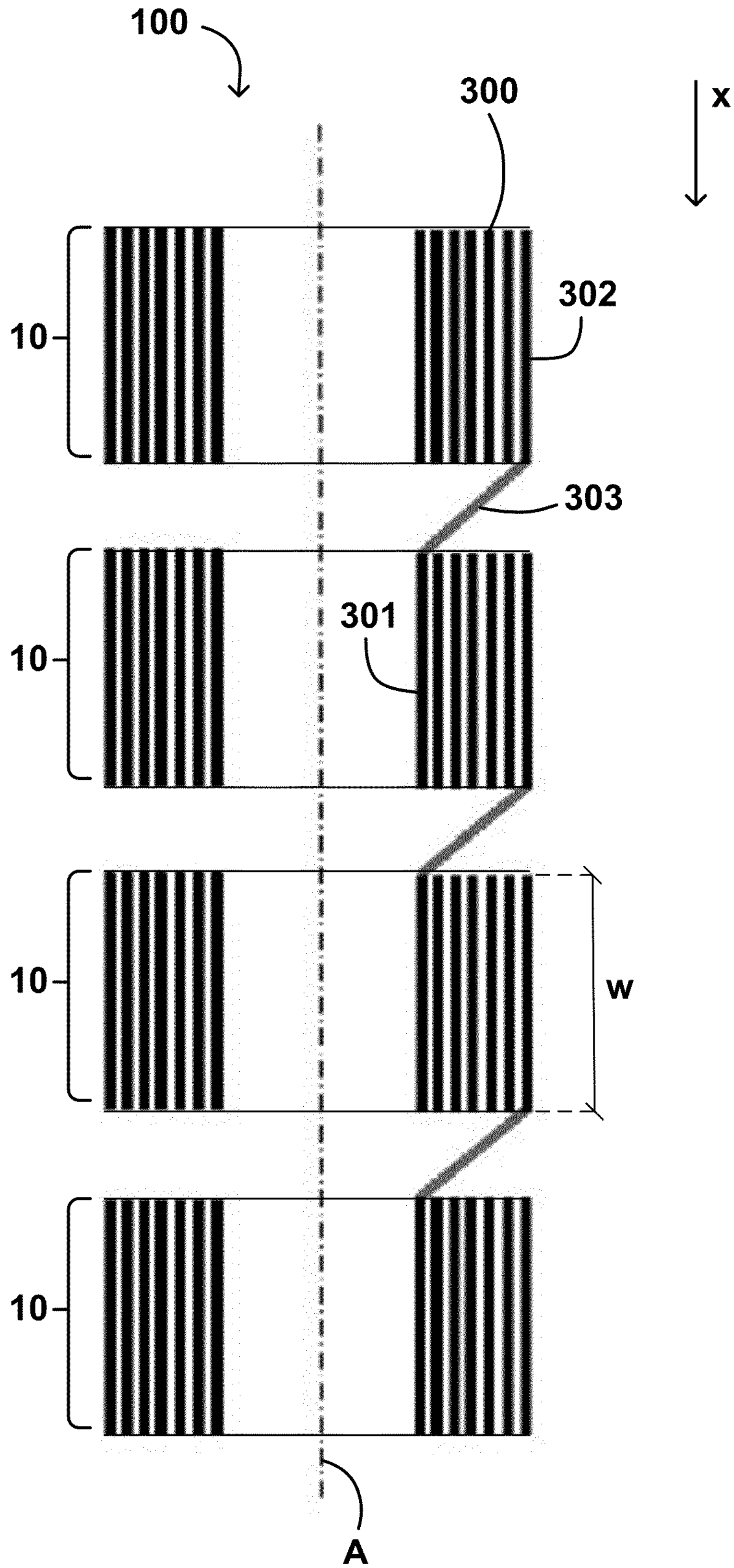
10,10c
10,10b
120
10,10d
102

FIG.2



DRY-TYPE TRANSFORMER

The present invention relates to a dry-type transformer comprising a winding with a tapping zone, with reduced losses in said winding.

BACKGROUND ART

Dry-type transformers for high voltage classes have been widely used in recent years in a number of utility and industrial installations because of their high reliability. Some of these dry-type transformers require the use of high voltages, high rated powers and a high regulating range, which lead to heating and hot-spot problems related to eddy and DC (or ohmic) losses in the windings of the transformer,

These eddy currents are induced by the magnetic flux generated by the current flowing through the winding, and they depend mainly on the module and direction of the magnetic flux: generally, it can be said that the more radial the magnetic flux, the higher the losses.

Also, in dry-type transformers requiring a high tapping range, when working in the lowest position of the transformer's tap-changer, high losses appear in the parts of the winding near to the connection points of the tap-changer, leading to a high hot-spot temperature within the zones surrounding said connection points.

In oil-type transformers, a regulation winding is employed to decrease hot spots created by the eddy currents along the winding; however, such a regulation winding may not be a suitable or appropriate solution for a dry-type transformer, since, because of its air-cooling system, it would require adding a very large and expensive regulation coil to the dry-type transformer.

The present invention aims to provide a dry-type transformer which solves at least partly the above drawbacks, by reducing the losses due to eddy currents, at least in the more problematic operating positions of the tap changer.

SUMMARY OF THE INVENTION

In a first aspect, the invention provides a dry-type transformer comprising a winding with a tapping zone, the tapping zone being the zone wherein at least two connections can be made, allowing to change the number of turns of the winding and thus change the turn ratio of the transformer, and with at least a first non-tapping zone, wherein the winding comprises a conductor having, in at least part of the tapping zone, a first width in the axial direction of the winding, and having, in at least part of the first non-tapping zone, a second width in the axial direction of the winding, the first width being smaller than the second width.

The use of a conductor having such a smaller width in the tapping zone reduces the axial length of this zone, and in particular reduces the gap of unused turns in the lower position of the tap changer of the transformer, i.e. the position in which the winding has a smaller number of turns. This reduction in the gap brings about a more axial magnetic flux, reducing the radial component thereof; as a consequence of this change in the magnetic flux, the eddy currents and corresponding losses caused by the radial magnetic flux in those non-tapping zones of the windings that are adjacent to the tapping zone are reduced.

Additional objects, advantages and features of embodiments of the invention will become apparent to those skilled in the art upon examination of the description, or may be learned by practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Particular embodiments of the present invention will be described in the following by way of non-limiting examples, with reference to the appended drawings, in which:

FIG. **1** depicts schematically a dry-type transformer comprising a high voltage winding and a low voltage winding, according to an embodiment of the present invention;

FIG. **2** depicts schematically the conductors of a high voltage winding of a dry-type transformer, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. **1** shows schematically a dry-type transformer according to an embodiment of the present invention. More particularly, it shows schematically the arrangement of the windings of a transformer, according to a partial section taken along a plane that contains the axis of the windings.

Dry type transformers according to embodiments of the present invention may be of the type wherein the transformer is designed to operate with a certain rated current flowing through the high voltage (HV) winding. Therefore, substantially the same current flows through all the conductors forming the winding, even if the winding may comprise several conductors in series with different physical features.

The transformer may comprise an HV winding **100** and a low voltage (LV) winding **200** inductively coupled with the HV winding, each winding comprising a conductor, and both windings being displayed in the figure in a usual arrangement wherein the LV winding is mounted coaxially inside the HV winding; the HV winding **100** may comprise a tapping zone **110**, two non-tapping zones **120**, and a tap-changer (not shown) which allows changing the turn ratio of the windings, in order to change the transforming relation of the dry type transformer. The tap-changer may comprise two connectors (not shown) which are connectable at different points of the conductor along the tapping zone **110** of the HV winding **100**, so as to exclude a plurality of turns of the HV winding, thus enabling a change in the turn ratio of the transformer.

It has to be noted that the conductor forming the HV winding may be formed by, for example, a plurality of conducting parts connected to each other by welding or using a connecting part, such as, for example, a non-conducting part engaging both conducting parts together to allow a suitable current flow through them.

By way of example, in FIG. **1**, according to this specific embodiment, the HV winding **100** may be formed by two sub-winding structures **101**, **102**, connected to each other at an intermediate point **111** of the tapping zone **110**. However, other embodiments may comprise a HV winding in a single structure, or more than two sub-winding structures, depending on the physical structure of the windings used to configure the transformer.

FIG. **2** shows schematically a portion of the HV winding of a transformer, according to a section taken along a plane that contains the axis (A) of the windings.

According to FIG. **2**, the conductor forming the HV winding **100** may be shaped as a strip **300** having a width w, which may be arranged forming a plurality of spiral-shaped "disks" **10**, the strip-shaped conductor having within each disk a uniform width in the axial direction of the winding. Furthermore, the disks may be interconnected with each other, and the spiral in each disk may have an inner strip end **301** and an outer strip end **302**. Each spiral-shaped disk **10** may be connected with the adjacent ones by means of a suitable electric coupling **303** connecting the outer strip end **302** of each disk to the inner strip end **301** of the following disk in such a way that the disks are connected in series forming the winding **100**. FIG. **2** shows four of such disks **10** connected to each other.

Furthermore, as seen in FIG. **1**, at least a portion **112** of the disks **10***a* in the tapping zone **110** may be configured in such a way that they comprise a strip-shaped conductor having a smaller width w_a, in the axial direction of the winding (direction x), than the width w_b of the strip-shaped conductor of the disks **10***b* of the non-tapping zone **120**. The portion of the disks **10***a* having a conductor with such a width w_a is shown with reference **112** in FIG. **1**, and the portion of the disks **10***b* having a conductor with such a width w_b are shown with reference **114** in FIG. **1**.

In this way the axial length of the tapping zone is reduced, thus reducing the gap of unused turns when the tap-changer works at a low range, i.e. the position in which the winding has a lower number of turns. This reduction allows reducing the losses related to the eddy currents caused by the radial magnetic flux in those non-tapping zones **120** of the windings adjacent to the tapping zone **110**.

According to an embodiment, the disks **10***a* of the tapping zone **110** may have a conductor with a width w_a in the axial direction of the HV winding **100** which may be between 40% and 80% of the width w_b of the disks of the non-tapping zone **120**, and may preferably be approximately 60% of the width of the disks of the non-tapping zone **120**.

Also, according to an embodiment, the conductors of the disks **10***a*, **10***c* of the tapping zone **110** are made of a material with a higher conductivity than the materials used on the disks **10***b*, **10***d* of the non-tapping zones **120**.

This improves the efficiency of the transformer when it is working with a high range in the tap changer, i.e. the position in which the winding has a higher number of turns: in this position, ohmic losses appear in the disks **10***a*, **10***c* of the tapping zone **110**, and this losses may be relevant in disks having a relatively small width, since ohmic losses will depend proportionally on the size of the conductor. Such losses can be reduced by using disks **10***a*, **10***c* with higher conductivity in the tapping zone **110**.

According to some embodiments, the disks **10***a*, **10***c* of the tapping zone **110** may be made of copper, and the disks **10***b*, **10***d* of the non-tapping zones **120** may be made of aluminum.

Using smaller disks in the tapping zone leads to a reduction of the losses when the tap changer works at a lower range, and making these disks of copper reduces the losses due to said reduction of the size of the disks, when the tap changer works at a higher range.

Furthermore, the conductor of a portion of the disks **10***c* at the ends of the tapping zone **110** adjacent to the non-tapping zones **120** may have a width w_c higher than w_a. This relatively higher width allows reducing the DC or ohmic losses in the disks **10***c*, in order to compensate the overall losses, which also comprise eddy losses, in the disks **10***c*, when the transformer is working at a high range in the tap changer. The portion of the disks **10***c* having a conductor with such a width w_c is shown with reference **113** in FIG. **1** (in the example, only one disk **10***c* in each winding structure is shown).

Also, according to an embodiment, the conductor of a portion of the disks **10***d* at the ends of the non-tapping zones **120** remote from the tapping zone **110**, may also have a width w_d bigger than w_b. In this way, a reduction of DC or ohmic losses is achieved in said disks **10***d*, in order to compensate the eddy losses caused by the radial magnetic flux in the ends of the non-tapping zones remote from the tapping zone. The portion of the disks **10***d* having such a width w_d is shown with reference **115** in FIG. **1** (in the example, only one disk **10***d* in each winding structure is shown).

It will be noted that each of the above features regarding the width and material of the conductor may be implemented in a dry-type transformer independently from each other, since each provides an effect that is not dependent on the others, although the combined effects may be advantageous.

According to experimental results, in a HV coil of a 25 MVA 66 kV transformer with a tapping range of ±18%, a reduction of approximately 40% of the losses caused by eddy currents has been achieved when the transformer is working at the lower position of the tap changer, and the relations between the widths are: w_a is 60% of w_b, w_c is the same as w_b, and w_d is 120% of w_b. Most of said reduction is found in the disks of the non-tapping zone (**120**) adjacent to the tapping zone (**110**), where a reduction of the hot spot temperature has been achieved from 210° C. to 116° C.

Although only a number of particular embodiments and examples of the invention have been disclosed herein, it will be understood by those skilled in the art that other alternative embodiments and/or uses of the invention and obvious modifications and equivalents thereof are possible. Furthermore, the present invention covers all possible combinations of the particular embodiments described. Reference signs related to drawings and placed in parentheses in a claim, are solely for attempting to increase the intelligibility of the claim, and shall not be construed as limiting the scope of the claim. Thus, the scope of the present invention should not be limited by particular embodiments, but should be determined only by a fair reading of the claims that follow.

The invention claimed is:

1. Dry-type transformer comprising a winding with a tapping zone, the tapping zone being the zone wherein at least two connections can be made, allowing to change the number of turns of the winding and thus change the turn ratio of the transformer, and with at least a first non-tapping zone, wherein the winding comprises a conductor having, in at least part of the tapping zone, a first width in the axial direction of the winding, and having, in at least part of the first non-tapping zone, a second width in the axial direction of the winding, the first width being smaller than the second width wherein the conductor of the winding is made of at least two materials with different conductivity; wherein a material with higher conductivity of the at least two materials is used in the conductor in the tapping zone where there is a smaller width.

2. Dry-type transformer according to claim **1**, wherein the conductor of the winding in at least part of the tapping zone is made of a first material and the conductor of at least part of the rest of the winding is made of a second material.

3. Dry-type transformer according to claim **1**, wherein the two materials are copper and aluminum.

4. Dry-type transformer according to claim **3**, wherein the conductor of the winding in at least part of the tapping zone is made of copper, and the conductor of the winding in at least part of the non-tapping zone is made of aluminum.

5. Dry-type transformer according to claim **1**, wherein a length of the conductor in the tapping zone adjacent to a non-tapping zone has a third width, in the axial direction of the winding, which is different with respect to the first width of the conductor.

6. Dry-type transformer according to claim **5**, wherein said third width is higher than the first width of the conductor.

7. Dry-type transformer according to claim **5**, wherein the third width is approximately equal to the second width.

8. Dry-type transformer according to claim **1**, wherein the first width is one of between 40% and 80% of the second width, and approximately 60% of the second width.

9. Dry-type transformer according to claim **1**, wherein at least part of the conductor is shaped as a strip.

10. Dry-type transformer according to claim **9**, wherein the conductor is arranged forming a plurality of spiral-shaped disks, the strip-shaped conductor having within each disk a uniform width in the axial direction of the winding.

11. Dry-type transformer according to claim **10**, wherein the strip-shaped conductor is made of the same material within each disk.

12. Dry-type transformer according to claim **1**, wherein a length of the conductor at the end of a non-tapping zone remote from the tapping zone has a fourth width in the axial direction of the winding, which is different with respect to the second width of the conductor.

13. Dry-type transformer according to claim **12**, wherein the fourth width is higher than the second width of the conductor.

14. Dry-type transformer according to claim **1**, wherein the winding is the high voltage winding of the transformer.

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